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(54) **Transparent photoreceptor overcoatings.**

(57) Highly transparent charge injection enabling species for electrophotographic overcoatings include copper (I) compounds dispersed throughout the overcoating or complexed into a charge transport matrix. The overcoatings contain an insulating, film forming continuous phase having charge transport molecules and the copper (I) compounds such as cuprous iodide.

**EP 0 433 055 A2**

## TRANSPARENT PHOTORECEPTOR OVERCOATINGS

This invention relates to electrophotography, and more particularly, to an improved overcoated electrophotographic imaging member and method of making the electrophotographic imaging member.

Generally, electrophotographic imaging processes involve the formation and development of electrostatic latent images on the imaging surface of a photoconductive member. The photoconductive member is usually imaged by uniformly electrostatically charging the imaging surface in the dark, and exposing the member to a pattern of activating electromagnetic radiation, such as light, which selectively dissipate the charge in the illuminated areas of the member to form an electrostatic latent image on the imaging surface. The electrostatic latent image is then developed with a developer composition containing toner particles which are attracted to the photoconductive member in image configuration. The resulting toner image may be transferred to a suitable receiving member such as paper.

The imaging surface of many photoconductive members is sensitive to wear, ambient fumes, scratches and deposits which adversely affect the electrophotographic properties of the imaging member. Overcoating layers have been proposed to overcome the disadvantageous characteristics of these photoreceptors. However, many of the overcoating layers adversely affect electrophotographic performance of the electrophotographic imaging member.

One type of insulating electrophotographic imaging member has at least one photoconductive layer and an overcoating layer comprising an insulating, film forming continuous phase comprising charge transport molecules and finely divided charge injection enabling particles dispersed in the continuous phase.

Overcoatings for photoreceptors have been disclosed in US-A-4,515,882. These overcoatings comprise an insulating film forming continuous phase comprising charge transport molecules and finely divided charge injection enabling particles dispersed in the continuous phase. The imaging members have at least one photoconductive layer and the overcoating layer. Where desired, a barrier layer may be provided in the device interposed between the photoconductive layer and the overcoating layer. The devices disclosed in US-A-4,515,882 can be employed in an electrophotographic imaging process in which the outer imaging surface of the overcoating layer is uniformly charged in the dark. A sufficient electric field is applied across the electrophotographic imaging member to polarize the charge injection enabling particles whereby the charge injection enabling particles inject charge carriers into the continuous phase of the overcoating layer. The charge carriers are transported to and trapped at the interface between the photoconductive layer, and opposite space charge in the overcoating layer is relaxed by charge emission from the charge injection enabling particles to the imaging surface. The overcoating layer is essentially electrically insulating prior to deposition of the uniform electrostatic charge on the imaging surface.

The mechanism by which charge passes through the overcoating to the photoreceptive surface in known devices is believed to involve the electric field, formed by corona charging of the electrophotographic device, instantly polarizing the charge injection enabling particles or species. Charge, for example, in the form of holes, is injected into the hole transport phase of the overcoating and is driven by the charging field to the interface between the overcoating and photoconductive layer. The charge is stopped at the interface by a blocking layer or because there is no injection into the photoreceptor. The negative space charge in the bulk of the overcoating is relaxed by a charge emission.

However, overcoatings such as those disclosed in US-A-4,515,882 suffer from the disadvantage of high light absorption and scattering in the coating due to pigment loading and particle size. Inorganic charge injection enabling particles mentioned in that patent include carbon black, molybdenum disulfide, silicon, tin oxide, antimony oxide, chromium dioxide, zinc dioxide, titanium oxide, magnesium oxide, manganese dioxide, aluminum oxides, colloidal silica, graphite, tin, aluminum, nickel, steel, silver, gold, other metals and their oxides, sulfides, halides and other salt forms, etc. Such charge injection enabling particles tend to reduce the photosensitivity of the photoreceptor. For example, one weight percent of carbon black pigment, which is the prime effective charge injection enabling species currently in use, reduces light transmission to the photosensitive layer by about 20%.

Electrophotographic devices have been proposed which include layers that are electrically conducting and transparent. For example, US-A-3,505,131 discloses a method of preparing a highly transparent cuprous iodide conductive film. US-A-3,677,816 discloses a method of producing transparent and electrically conducting coatings of copper iodide. These films are used as an electrode or ground in multi-electrode electrostatic systems.

Copper iodide has also been used in electrophotography in protective layers, as disclosed in Japanese Unexamined Patent Application No. 59-159 (1984). The disclosed protective layer comprises 10-60 weight percent Cu iodide based on binder resin.

Another use of copper iodide in electrophotography is disclosed in US-A-4,133,933. Cuprous iodide is pro-

vided in an electrosensitive recording sheet, and is whitened by adding an alkaline substance for increasing the resistance of the cuprous iodide and for increasing the contrast of the recorded mask.

In the above-described devices, copper iodide is utilized primarily to achieve high electrical conductivity.

There continues to be a need for improved layers in electrophotographic imaging members which are highly transparent and which will protect the imaging member from wear, ambient fumes and the like.

In accordance with the present invention, there is provided an electrophotographic imaging member, including a substantially transparent layer comprising charge transport molecules and charge injection enabling species, characterised in that the charge injection enabling species is a copper (I) compound. In a preferred form, the invention provides an electrophotographic imaging member having at least one photoconductive layer and an overcoating layer comprising an insulating, film forming continuous phase comprising charge transport molecules and highly transparent charge injection enabling species. Copper (I) compounds such as cuprous iodide are utilized as the charge injection enabling species. Where desired, a barrier layer may be interposed between the photoconductive layer and the overcoating layer.

A more complete understanding of the present invention can be obtained by reference to the accompanying drawing which shows a cross-sectional view of a multilayer photoreceptor of the invention.

The electrophotographic imaging member of the present invention comprises an overcoating layer, preferably adjacent a photoconductive layer. The overcoating layer comprises charge transport molecules and highly transparent charge injection enabling particles in an insulating film forming continuous phase. The overcoatings of the present invention may be used for negative and positive photoreceptors and are of particular interest for positive charging layered photoreceptors where the photoconductive charge generation and injection layer is on the top surface, less than about one  $\mu\text{m}$  thick and subject to wear which, in the absence of the present invention, would lead to short receptor life.

Any suitable insulating film forming binder having a very high dielectric strength and good electrically insulating properties may be used in the continuous charge transporting phase of the overcoating of the present invention. The binder itself may be a charge transporting material or a material capable of holding transport molecules in solid solution or as a molecular dispersion. A solid solution is defined as a composition in which at least one component is dissolved in another component and which exists as a homogeneous solid phase. A molecular dispersion is defined as a composition in which particles of at least one component are dispersed in another component, the dispersion of the particles being on a molecular scale.

Typical film forming binder materials that are not charge transporting materials include thermoplastic and thermosetting resins such as polycarbonates, polyesters, polyamides, polyurethanes, polystyrenes, polyarylethers, polyarylsulfones, polybutadienes, polysulfones, polyethersulfones, polyethylenes, polypropylenes, polyimides, polymethylpentenes, polyphenylene sulfides, polyvinylacetate, polysiloxanes, polyacrylates, polyvinylacetals, polyamides, amino resins, phenylene oxide resins, terephthalic acid resins, epoxy resins, phenolic resins, polystyrene and acrylonitrile copolymers, polyvinylchloride, vinyl chloride and vinyl acetate copolymers, acrylate copolymers, alkyd resins, cellulosic film formers, poly(amide-imide), styrene-butadiene copolymers, vinylidenechloride-vinylchloride copolymers, vinyl acetate-vinylidenechloride copolymers, styrene alkyd resins, fluorocarbon resins, and the like.

Typical film forming binder materials that have charge transport capabilities are substantially non-absorbing in the spectral region of intended use, but are active in that they are capable of transporting charge carriers injected by the charge injection enabling particles in an applied electric field. The charge transport binder may be a hole transport film forming polymer or an electron transport film forming polymer. Charge transporting film forming polymers are well known in the art and include those enumerated in US-A-4,515,882. Other transport polymers include arylamine compounds disclosed in US-A-4,806,443, 4,806,444 and 4,818,650, as well as polysilylenes disclosed in US-A-4,618,551, 4,774,159, 4,772,525 and 4,758,488.

The film forming binder should have an electrical resistivity of at least about  $10^{13}$  ohm-cm. It should be capable of forming a continuous film and be substantially transparent to activating radiation to which the underlying photoconductive layer is sensitive. In other words, the transmitted activating radiation should be capable of generating charge carriers, i.e. electron-hole pairs, in the underlying photoconductive layer or layers. A transparency range of between about 35 percent and about 100 percent can provide satisfactory results depending upon the specific photoreceptors utilized. A transparency of at least about 50 percent is preferred for greater speed with optimum speeds being achieved at a transparency of at least greater than 90 percent. Transparency is meant to refer to the property of permitting the passage of radiations in the spectral region at which the underlying photoconductive layer or layers are sensitive.

Any suitable charge transport molecule capable of acting as a film forming binder or which is soluble or dispersible on a molecular scale in a film forming binder may be utilized in the continuous phase of the overcoating of this invention. The charge transport molecules should be capable of transporting charge carriers injected by the charge injection enabling particles in an applied electric field. The charge transport molecules

may be hole transport molecules or electron transport molecules. Where the charge transport molecule is capable of acting as a film forming binder as indicated above, it may be employed, if desired, to function as both an insulating binder for the charge injection enabling particles and as the continuous charge transporting phase without the necessity of incorporating a different charge transport molecule in solid solution or as a molecular dispersion therein.

Such charge transporting materials are well known in the art. Diamines, pyrazolines, substituted fluorenes, oxidiazoles, hydrazones, tri-substituted methanes, transparent organic non-polymeric transport materials, and the like, as disclosed in US-A-4,515,882, are examples of well known charge transporting materials.

When the charge transport molecules are combined with an insulating film forming binder, the amount of charge transport molecule which is used may vary depending upon the particular charge transport material, its compatibility with (e.g. solubility in) the continuous insulating film forming binder phase of the overcoating layer, and the like. Satisfactory results have been obtained using the proportions normally used to form the charge transport medium of photoreceptors containing a charge transport component and a charge generating component.

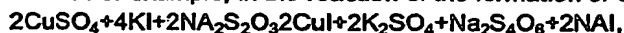
When the overcoating layers are prepared with only insulating film forming binder and charge transport molecules in solid solution or molecule dispersion in the film forming binder, the overcoating layer remains insulating after charging until at least the image exposure step. However, when sufficient charge injection enabling particles are dispersed in an overcoating layer containing an insulating film forming continuous phase capable of transporting charge carriers, the overcoating layer acquires the capability of being an insulator until a sufficient electric field is applied to polarize the charge injection enabling particles. Then, the charge injection enabling particles inject charge carriers into the continuous phase of the overcoating layer. The charge carriers are transported to and trapped at the interface between the underlying photoconductive layer and the overcoating layer. Opposite space charge in the overcoating layer is relaxed by charge emission from the charge injection enabling particles to the outer imaging surface of the overcoating.

The charge injection enabling particles of the present invention are comprised of a copper (I) compound. Copper (I) compounds have desirable properties in electrophotographic applications; for example, copper (I) compounds have desirable electrical properties, which properties are useful in electrically conducting ground planes and other conductive elements of a photoreceptor. Copper (I) compounds which can be used in the invention include cuprous iodide, cuprous bromide and cuprous chloride. A preferred copper (I) compound is cuprous iodide.

Cuprous iodide is an electrical conductor in bulk and film form, and is colorless and therefore highly transparent in the visible region by virtue of the  $d^{10}$  electronic configuration of the  $Cu^+$  ion, the colorless  $I^-$  ion and the lack of charge transfer bands in the visible region. The transparent properties of cuprous iodide are desirable in the present invention. High pigment loadings of  $CuI$  are possible with little or no light absorption to reduce the photosensitivity of the photoreceptor.

The charge injection properties of copper (I) compounds have not previously been studied in a polymer transport matrix. Furthermore, relative to other transparent conductors such as  $Cd_2SnO_4$  or the tin oxides containing  $In$  or  $Sb$ , cuprous iodide is generally considered to be less environmentally hazardous.

Cuprous iodide can adsorb surface moisture, oxygen, iodide and other species that may be used to control the charge injecting properties of the material in the matrix. The presence or absence of moisture, for example, may be controlled by the method and length of time of drying. The presence or absence of iodine may also be controlled. For example, in the reaction of the formation of  $CuI$



the copper (II) iodide formed initially by the combination of copper (II) ion and iodide ion in aqueous solution decomposes almost immediately by a redox reaction to yield copper (I) iodide and free iodine. The amount of free iodine in the sample may be controlled or eliminated by varying the amount of thiosulfate. The absorption of iodine in the sample may be desirable since its absorption increases the conductivity of the copper (I) iodide.

Light also has an effect on the surface properties of  $CuI$ , although its sensitivity to light is much less than that of  $CuBr$  which is much less than that of  $CuCl$ . Exposure to light will increase the conductivity of copper (I) iodide. This convenient type of controlling surface properties is not known for other transparent conductors such as  $SnO_2$ , doped  $SnO_2$  or  $Cd_2SnO_4$ .

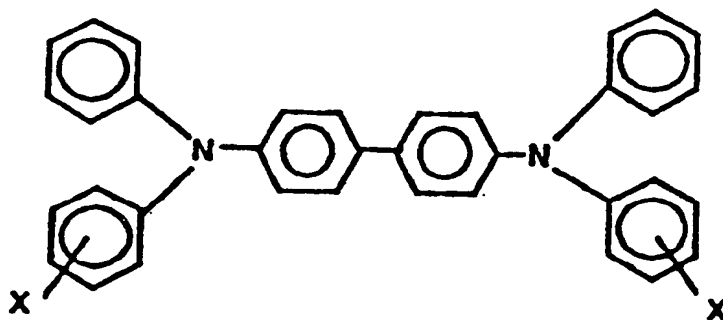
Generally, the overcoating layer should contain at least about 0.1 percent by weight of the charge injection enabling particles based on the total weight of the overcoating layer. At lower concentrations, a noticeable residual charge tends to form, which can be compensated during development by applying an electric bias as is known in the art. The upper limit for the amount of the charge injection enabling particles to be used depends upon the relative quantity of charge flow desired through the overcoating layer, but should be less than that which would reduce the transparency of the overcoating to a value less than about 35 percent and which would render the overcoating too conductive.

The amount of charge injection enabling particles which can be loaded in the overcoating layer of the present invention may range from about 1 to about 25 weight percent based on the total weight of the overcoating layer. The particular loading of charge injection enabling particles will depend on the desired percent transmission, desired conductivity, the binding capability of the resin, the desired mechanical properties of the imaging member, e.g., flexibility, and the residual voltage on the photoreceptor. With copper (I) compounds such as cuprous iodide, the loading may be from about 1 to about 25 weight percent based on weight of the total weight of the overcoating layer. A particularly preferred loading of copper iodide is 3 to 20 weight percent and most preferably about 10 to 20 weight percent. With such loadings, transparent layers having a resistivity greater than about  $10^{11}$  ohms-cm can be obtained.

The particle size of the charge injection enabling particles should be less than about 25  $\mu\text{m}$ , preferably less than about 1  $\mu\text{m}$ , and for molecular dispersions less than the wavelength of light utilized to expose the underlying photoconductive layers. In other words, the particle size should be sufficient to maintain the overcoating layer substantially transparent to the wavelength of light to which the underlying photoconductive layer or layers are sensitive. A particle size between about 10 nm and about 50 nm has been found most suitable for light sources having a wavelength greater than about 400 nm. The particle size of the charge injection enabling particles of the present invention may be controlled by the preparative route used to make the copper (I) compounds and their dispersions.

In addition to the advantages already mentioned, cuprous iodide and other copper (I) compounds have the added advantage that they can form donor-acceptor complexes, for example, with amines or ammonia by interaction between the nitrogen lone-pair of electrons and the Cu(I) ion. Thus, the potential exists for weak complexes to form in solution between CuI and material comprising the charge transport layer for additionally transparent overcoatings.

For example, a charge transport layer may comprise a charge transport compound having the general formula :



wherein X is selected from the group consisting of an alkyl group, having from 1 to about 4 carbon atoms, and chlorine. This particular compound will hereinafter be referred to as TAA. Weak complexes can form in solution between CuI and TAA. A surface of adsorbed TAA on CuI in the matrix may also be envisioned, establishing an intimate electronic contact between the injecting and transport series. Transparency may be increased if the charge transporting molecules promote wetting of the matrix to CuI which will reduce voids at the interface to enhance the index of refraction gradient across the interface.

Other charge transport matrix materials which may be molecularly complexed with CuI include phosphine derivatives of TAA and polysilylenes disclosed in U.S. Patent Nos. 4,618,551, 4,774,159, 4,772,525 and 4,758,488.

The components of the overcoating layer may be mixed together by conventional means. Typical mixing means include stirring rods, ultrasonic vibrators, magnetic stirrers, paint shakers, sand mills, roll pebble mills, sonic mixers, melt mixing devices and the like. It is important, however, that if the insulating film forming binder is a different material than the charge transport molecules, the charge transport molecules must either dissolve in the insulating film forming binder or be capable of being molecularly dispersed in the insulating film forming binder. A solvent or solvent mixture for the film forming binder and charge transport molecules may be utilized if desired. Preferably, the solvent or solvent mixture should dissolve both the insulating film forming binder and the charge transport molecules. The solvent selected should not adversely affect the underlying photoreceptor. For example, the solvent selected should not dissolve or crystallize the underlying photoreceptor.

The overcoating mixture may be applied to the photoconductive member or to a blocking layer, if a blocking layer is utilized. The overcoating mixture may be applied by known techniques. Typical coating techniques include all spraying techniques, draw bar coating, dip coating, gravure coating, silk screening, air knife coating,

reverse roll coating, and extrusion techniques. Conventional drying or curing techniques may be utilized to dry the overcoating. The drying or curing conditions should be selected to avoid damaging the underlying photoreceptor. For example, the overcoating drying temperatures should not cause crystallization of amorphous selenium when an amorphous selenium photoreceptor is used.

5 The thickness of the overcoating layer after drying or curing may be preferably between about 1  $\mu\text{m}$  and about 15  $\mu\text{m}$ . Generally, overcoating thicknesses less than about 1  $\mu\text{m}$  fail to provide sufficient protection for the underlying photoreceptor. Greater protection is provided by an overcoating thickness of at least about 3  $\mu\text{m}$ . Resolution of the final toner image begins to degrade when the overcoating thickness exceeds about 15  $\mu\text{m}$ . Clearer image resolution is obtained with an overcoating thickness less than 8  $\mu\text{m}$ . Thus, an overcoating  
10 thickness of between 3  $\mu\text{m}$  and about 8  $\mu\text{m}$  is preferred for optimum protection and image resolution.

The final dried or cured overcoating should be substantially insulating prior to charging. Satisfactory results may be achieved when the final overcoating has a resistivity of at least about  $10^{11}$  ohm-cm, preferably  $10^{13}$  ohm-cm, at fields low enough essentially to eliminate injection from the charge injection enabling particles into the transport molecule. The overcoating is substantially electrically insulating in the dark. The charge injection  
15 enabling particles will therefore not polarize in less than about  $10^{-12}$  second and inject charge carriers into the continuous charge transporting phase in less than about 10 microseconds when an applied electric field less than about 5 volts per  $\mu\text{m}$  is applied across the imaging member from the conductive substrate to the outer surface of the overcoating.

The final dried or cured overcoating of the present invention is substantially non-absorbing in the spectral region at which the underlying photoconductive layer or layers are sensitive. The expression "substantially non-absorbing" is defined as a transparency of between about 35 percent and about 90 percent in the spectral region at which the underlying photoconductive layer or layers are sensitive. A transparency of at least about 50 percent in the spectral region at which the underlying photoconductive layer or layers are sensitive is preferred for a balance of electrical and optical properties in the coating speed with optimum speeds being achieved at  
25 a transparency of at least greater than 90 percent.

The overcoatings of the present invention may also reduce emission of toxic Se, Te and As particles generated from alloy photoreceptors of xerographic machines used in making copies. They may also inhibit crystallization of Se/Te alloys by chemical exposure to, e.g., mercury vapor in dental offices. Further, the overcoatings prevent extraction of charge transport molecules from layered photoreceptors in use with liquid  
30 developers.

Any suitable electrophotoconductive member may be overcoated with the overcoating layer of this invention. Generally, an electrophotoconductive member comprises one or more photoconductive layers on a supporting substrate.

The substrate may be opaque or substantially transparent and may comprise numerous suitable materials  
35 having the required mechanical properties. Accordingly, this substrate may comprise a layer of a non-conductive or conductive material such as an inorganic or an organic composition. If the substrate comprises non-conductive material, it is usually coated with a conductive composition. As insulating non-conducting materials there may be employed various resins known for this purpose including polyesters, polycarbonates, polyamides, polyurethanes, and the like. The insulating or conductive substrate may be flexible or rigid and  
40 may have any number of many different configurations such as, for example, a plate, a cylindrical drum, a scroll, an endless flexible belt, and the like. Preferably, the insulating substrate is in the form of an endless flexible belt and is comprised of a commercially available polyethylene terephthalate polyester known as Mylar available from E.I. du Pont de Nemours & Co.

The thickness of the substrate layer depends on numerous factors, including economical considerations, and thus this layer may be of substantial thickness, for example, over 200  $\mu\text{m}$ , or of minimum thickness less than 50  $\mu\text{m}$ , provided there are no adverse affects on the final photoconductive device. In one embodiment, the thickness of this layer ranges from about 65  $\mu\text{m}$  to about 150  $\mu\text{m}$ , and preferably from about 75  $\mu\text{m}$  to about 125  $\mu\text{m}$ .  
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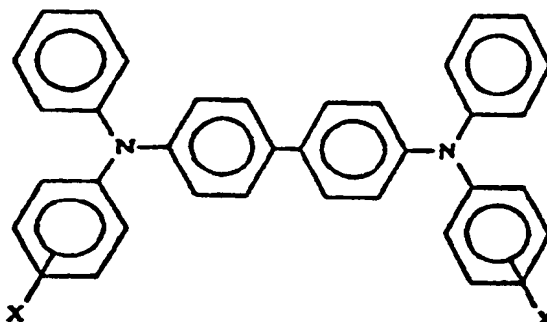
A conductive layer or ground plane which may comprise the entire support or be present as a coating on a non-conductive layer may comprise any suitable material including, for example, aluminum, titanium, nickel, chromium, brass, gold, stainless steel, carbon black, graphite and the like. The conductive layer may vary in thickness over substantially wide ranges depending on the desired use of the electrophotographic member. Accordingly, the conductive layer can generally range in thickness of from about 5 nm to many centimeters. When a flexible photoresponsive imaging device is desired, the thickness may be between about 10 nm to about  
55 75 nm, and more preferably from any 10 nm to about 20 nm.

Any suitable photoconductive layer or layers may be overcoated with the overcoating layer of this invention. The photoconductive layer or layers may be inorganic or organic. Typical inorganic photoconductive materials include well known materials such as amorphous selenium, selenium alloys, halogen-doped selenium alloys

such as selenium-tellurium, selenium-tellurium-arsenic, selenium- arsenic, and the like, cadmium sulfo-selenide, cadmium selenide, cadmium sulfide, zinc oxide, titanium dioxide and the like. Typical organic photoconductors include phthalocyanines, quinacridones, pyrazolones, polyvinylcarbazole-2,4,7-trinitrofluorenone, anthracene and the like. Many organic photoconductors may be used as particles dispersed in a resin binder.

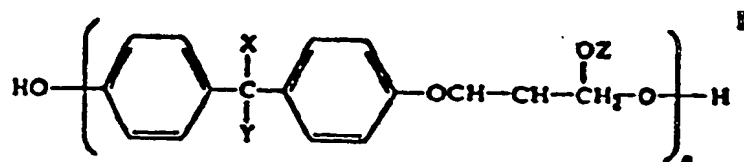
Any suitable multilayer photoconductors may also be employed with the overcoating layer of this invention. The multilayer photoconductors comprise at least two electrically operative layers, a photogenerating or charge generating layer and a charge transport layer. Examples of photogenerating layers include trigonal selenium, various phthalocyanine pigments such as the X-form of metal free phthalocyanine described in US-A-3,357,989, metal phthalocyanines such as copper phthalocyanine, quinacridones available from du Pont under the tradename Monastral Red, Monastral violet and Monastral Red Y, substituted 2,4-diamino-triazines disclosed in US-A-3,442,781, polynuclear aromatic quinones available from Allied Chemical Corporation under the tradename Indofat Double Scarlet, Indofast Violet Lake B, Indofast Brilliant Scarlet and Indofast Orange. Examples of photosensitive members having at least two electrically operative layers include the charge generating layer and diamine containing transport layer members disclosed in US-A-4,254,990 ; dyestuff generator layer and oxadizole, pyrazalone, imidazole, bromopyrene, nitrofluorene and nitronaphthalimide derivative containing charge transport layer members disclosed in US-A-3,895,944 ; generator layer and hydrazone containing charge transport layer and a tri-aryl pyrazoline compound containing charge transport layer members disclosed in US-A-3,837,851 ; and the like.

A preferred multilayered photoconductor comprises a charge generating layer comprising a layer of photoconductive material and a contiguous charge transport layer of a polycarbonate resin material having a molecular weight of from about 20,000 to about 120,000 having dispersed therein from about 25 to about 75 percent by weight of one or more compounds having the general formula :

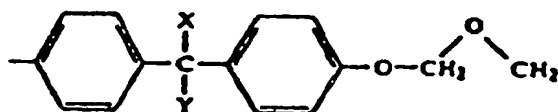
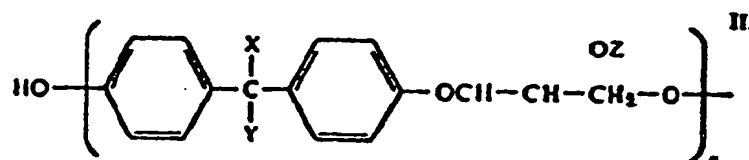


wherein X is selected from the group consisting of an alkyl group having from 1 to about 4 carbon atoms and chlorine. The photoconductive layer exhibits the capability of photogeneration of holes and injection of the holes. The charge transport layer is substantially non-absorbing in the spectral region at which the photoconductive layer generates and injects photogenerated holes from the photoconductive layer and transports the holes through the charge transport layer. Other examples of charge transport layers capable of supporting the injection of photogenerated holes of a charge generating layer and transporting the holes through the charge transport layer include triphenylmethane, bis(4-diethylamine-2- methylphenyl) phenylmethane ; 4'-4"-bis(diethylamino)- 2',2"-dimethyltriphenyl methane and the like dispersed in an inactive resin binder.

Numerous inactive resin materials may be employed in the charge transport layer including those described, for example, in US-A-3,121,006. The resinous binder for the charge transport layer may be identical to the resinous binder material employed in the charge generating layer. Typical organic resinous binders include thermoplastic and thermosetting resins such as polycarbonates, polyesters, polyamides, polyurethanes, polystyrenes, polyarylethers, polyarylsulfones, polybutadienes, polysulfones polyethersulfones, polyethylenes, polypropylenes, polyimides, polymethylpentenes, polyphenylene sulfides, polyvinyl acetate, polysiloxanes, polyacrylates, polyvinyl acetals, amino resins, phenylene oxide resins, terephthalic acid resins, epoxy resins, phenolic resins, polystyrene and acrylonitrile copolymers, polyvinylchloride, vinylchloride and vinyl acetate copolymers, acrylate copolymers, alkyd resins, cellulosic film formers, poly(amide-imide), styrene-butadiene copolymers, vinylidenechloride-vinylchloride copolymers, vinylacetate-vinylidenechloride copolymers, styrenealkyd resins, and the like. These polymers may be block, random or alternating copolymers. Excellent results may be achieved with a resinous binder material comprising a poly(hydroxyether) material selected from the group consisting of those of the following formulas :



and



wherein X and Y are independently selected from the group consisting of aliphatic groups and aromatic groups, Z is a hydrogen, an aliphatic group or an aromatic group, and n is a number of from about 50 to about 200.

These poly(hydroxyethers), some of which are commercially available from Union Carbide Corporation, are generally described in the literature as phenoxy resins or epoxy resins.

Examples of aliphatic groups for the poly(hydroxyethers) include those containing from about 1 carbon atom to about 30 carbon atoms, such as methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, decyl, pentadecyl, eicododecyl, and the like. Preferred aliphatic groups include alkyl groups containing from about 1 carbon atom to about 5 carbon atoms, such as methyl, ethyl, propyl, and butyl. Illustrative examples of aromatic groups include those containing from about 6 carbon atoms to about 25 carbon atoms, such as phenyl, naphthyl, anthryl, and the like, with phenyl being preferred. The aliphatic and aromatic groups can be substituted with various known substituents, including, for example, alkyl, halogen, nitro, sulfo and the like.

Examples of the Z substituent include hydrogen as well as aliphatic aromatic, substituted aliphatic and substituted aromatic groups as defined herein. Furthermore Z can be selected from carboxyl, carbonate, and other similar groups, resulting in for example, the corresponding esters, and carbonates of the poly(hydroxyethers).

Preferred poly(hydroxyethers) include those wherein X and Y are alkyl groups, such as methyl, Z is hydrogen or a carbonate group, an n is a number ranging from about 75 to about 100. Specific preferred poly(hydroxyethers) include Bakelite, phenoxy resins PKHH, commercially available from Union Carbide Corporation and resulting from the reaction of 2,2-bis(4-hydroxy-phenylpropane), or bisphenol A, with epichlorohydrin, an epoxy resin, Araldite R 6097, commercially available from CIBA, the phenylcarbonate of the poly(hydroxyethers) wherein Z is a carbonate grouping, which material is commercially available from Allied Chemical Corporation, as well as poly(hydroxyethers) derived from dichloro bisphenol A, tetrachloro bisphenol A, tetrabromo bisphenol A, bisphenol F, bisphenol ACP, bisphenol L, bisphenol V, bisphenol S, and the like.

The photogenerating layer containing photoconductive compositions and/or pigments and the resinous binder material generally ranges in thickness from about 0.1  $\mu\text{m}$  to about 5.0  $\mu\text{m}$ , and preferably has a thickness of from 0.3  $\mu\text{m}$  to about 1  $\mu\text{m}$ . Thicknesses outside these ranges can be selected providing the objectives of the present invention are achieved.

The photogenerating composition or pigment is present in the poly(hydroxyethers) resinous binder composition in various amounts. Generally from about 10 percent by volume to about 60 percent by volume of the photogenerating pigment is dispersed in about 40 percent by volume to about 90 percent by volume of the poly(hydroxyether) binder. Preferably from about 20 percent by volume to about 30 percent by volume of the photogenerating pigment is dispersed in about 70 percent by volume to about 80 percent by volume of the poly(hydroxyether) binder composition. In one embodiment about 25 percent by volume of the photogenerating pigment is dispersed in about 75 percent by volume of the polyhydroxyether binder composition.

Other typical photoconductive layers include amorphous or alloys of selenium such as selenium-arsenic, selenium-tellurium-arsenic, selenium-tellurium, selenium-arsenic-antimony, halogen doped selenium alloys, cadmium sulfide and the like.

Generally, the thickness of the transport layer is between about 5 to about 100  $\mu\text{m}$ , but thicknesses outside this range can also be used. The charge transport layer should be an insulator to the extent that the electrostatic



charge placed on the charge transport layer is not conducted in the absence of illumination at a rate sufficient to prevent formation and retention of an electrostatic latent image thereon. In general, the ratio of the thickness of the charge transport layer to the charge generator layer is preferably maintained from about 2 : 1 to 200 : 1, and in some instances as great as 400 : 1.

The following are examples of overcoatings prepared with an insulating film forming binder polymer, Merlon M-50F polycarbonate, available from Mobay Chemical Company, an active hole transporting material TAA and a charge injecting enabling particulate material cuprous iodide. The examples are intended to be illustrative only. The invention is not intended to be limited to the materials, conditions, process parameters and the like recited herein.

#### Comparative Example I

The solution which was used for the spray application of the overcoating consisted of 16.3 gms of Merlon M-50F, 11.2 gms of TAA (40 percent weight), 660 gms of methylene chloride and 440 gms of 1,1,2 trichloroethane. This solution did not contain the charge injection enabling particles. It was applied by spray coating to a brush grained aluminum plate and clear Mylar film. The coating was applied with a conventional automatic spray gun Model 21 manufactured by the Binks Manufacturing Co. of Franklin Park, Ill. The coating was dried at 110°C for 30 minutes and had a measured thickness of 4  $\mu$ m. The visible light transmittance of the overcoating as measured on the clear Mylar substrate was 99.9 percent. The overcoating on the aluminum plate was evaluated for charge injection by corona charging with a potential of +5000 and -5000 volts applied to the corotron wire. The charge on the surface of the overcoating was measured with a conventional electrostatic voltmeter. The charge and measure cycle was repeated several times to determine the stability of the charge on the surface of the overcoatings. The results of these charge and measure cycles are as follows.

Corotron Voltage		
	+ 5000 volts	-5000 volts
Cycle	Surface Potential	
1	+ 56 volts	-248 volts
2	+ 136 volts	-264 volts
3	+ 168	-280 volts

#### Example II

The procedure described in Example I was repeated except that the solution for the spray application of the overcoating consisted of 16.3 gms of Merlon M-50F, 11.2 gms of TAA (40 percent weight), 0.275 gms of cuprous iodide (1 percent weight), 660 gms of methylene chloride and 440 gms of 1,1,2 trichloroethane. The visible light transmittance of the overcoating was 99.9 percent. The results of the charge and measure cycles are as follows :

Corotron Voltage		
	+ 5000 volts	-5000 volts
Cycle	Surface Potential	
1	+ 50 volts	-18 volts
2	+ 80 volts	-20 volts
3	+ 88	-24 volts

#### Example III

The procedure described in Example I was repeated except that the solution for the spray application of the overcoating consisted of 16.3 gms of Merlon M-50F, 11.2 gms of TAA (40 percent weight), 1.375 gms of cuprous iodide (5 percent weight), 660 gms of methylene chloride and 440 gms of 1,1,2 trichloroethane. The visible light transmittance of the overcoating was 97.7 percent. The results of the charge and measure cycles

are as follows :

Corotron Voltage		
	+ 5000 volts	-5000 volts
Cycle	Surface Potential	
1	+ 24 volts	-6 volts
2	+ 32 volts	-8 volts
3	+ 32 volts	-8 volts

#### Example IV

The procedure described in Example I was repeated except that the solution for the spray application of the overcoating consisted of 16.3 gms of Merlon M-50F, 11.2 gms of TAA (40 percent weight), 2.75 of cuprous iodide (10 percent weight), 660 gms of methylene chloride and 440 gms of 1,1,2 trichloroethane. The visible light transmittance of the overcoating was 93.0 percent. The results of the charge and measure cycles are as follows.

Corotron Voltage		
	+ 5000 volts	-5000 volts
Cycle	Surface Potential	
1	+ 8 volts	-2 volts
2	+ 14 volts	-2 volts
3	+ 16 volts	-4 volts

#### Example V

The procedure described in Example I was repeated except that the solution for the spray application of the overcoating consisted of 16.3 gms of Merlon M-50F, 11.2 gms of TAA (40 percent weight), 4.125 gms of cuprous iodide (15 percent weight), 660 gms of methylene chloride and 440 gms of 1,1,2 trichloroethane. The visible light transmittance of the overcoating was 91.2 percent. The results of the charge and measure cycles are as follows.

Corotron Voltage		
	+ 5000 volts	-5000 volts
Cycle	Surface Potential	
1	+ 8 volts	-2 volts
2	+ 16 volts	-2 volts
3	+ 16 volts	-4 volts

These results indicate that, without the charge injection enabling particles, the 4  $\mu$ m thick insulating film forming binder and charge transport molecule layer charges to an unacceptable high voltage level. This level is reduced as larger amounts of the charge injection enabling particles are introduced into the insulating film forming binder and charge transport molecules. This indicates that cuprous iodide is an effective charge injection enabling particulate material that injects charge carriers into the continuous phase of the overcoating layer. The charge carriers are transported through the overcoating layer and to the conductive substrate where they combine with the opposite polarity charge. Opposite space charge in the overcoating layer is relaxed by charge emission from the charge injection enabling particles to the outer imaging surface of the overcoating.

#### Example VI

The solutions prepared as described in Examples II, III, IV and V were spray coated onto organic photoreceptors which had a ground plane 1, a charge transport layer 2 and a charge generating layer 3. An electrical charge blocking layer 4 was applied to the organic Photoreceptor of the Figure prior to the application of the overcoating 5 to trap the charge carriers which are produced by the overcoating during the application of the electric charge field to the overcoated photoreceptor. The electrical charge blocking layer consisted of about 1.0  $\mu\text{m}$  of a one to one weight ratio of zirconium acetylacetonate in Butvar B-72 from the Monsanto Polymers and Petrochemicals Co. of St. Louis Mo. The coating was applied using the spray coating equipment described in Example I. The coating was dried at 110°C for 30 minutes. The overcoating was applied to the organic photoreceptor with the electrical charge blocking layer by use of the spray coating equipment described in Example I. A photoreceptor with the electrical charge blocking layer was spray coated with each of the overcoatings of Examples II, III, IV and V for print testing and another was half coated for electrical cycling measurements. The overcoated photoreceptors were dried at 110°C for 30 minutes

The electrical measurements were made in a cycling scanner at a rotational rate for the photoreceptor of 24 revolutions per minute. The charging was done at a constant current of 3.6 microamperes and a Xerox 4045 machine erase lamp was used to discharge the photoreceptor before recharging. The voltage on the photoreceptor was measured at 0.20 and 1.12 seconds after charging and after exposure to the erase lamp. The difference between the voltage measured at 0.20 and 1.12 seconds after charging divided by the difference in the measurement time corresponds to the dark decay of the voltage on the photoreceptor. The photoreceptors which were overcoated with the overcoating materials that had less than 5 percent weight of cuprous iodide showed a wide circumferential variation in the initial voltage measured at 0.20 seconds after charging. The initial, residual and dark decay voltages decreased with increasing loading of the cuprous iodide in the overcoatings. The largest changes occurred for loadings of from 0 to 5 weight percent of cuprous iodide in the overcoating. The initial voltage decreased from 1200 volts to 740 volts indicating that the overcoating was effective in enabling injection and the charge was trapped at the interface of the photoreceptor.

The initial voltage on the photoreceptor was the same for the overcoated and unovercoated sides when the overcoating contained 15 weight percent of cuprous iodide. Cycling of the photoreceptor resulted in a significant increase in the dark decay to 100 volts for the unovercoated side as it degraded under the action of the corona from the charging corotron. There was no significant change in the initial voltage and dark decay for the overcoated side of the photoreceptor. The residual voltage on the overcoated side of the photoreceptor increased to 75 volts after 200 cycles while that on the unovercoated side stabilized at 16 volts. The overcoating that contained 15 weight percent of cuprous iodide had the lowest residual voltage and best cycling characteristics.

Print tests illustrated that the photoreceptor with the overcoating that contained 15 weight percent of cuprous iodide gave good quality toner developed line copy as compared to the unovercoated photoreceptor. No blurring of the developed image was observed although there was a slight graininess to the toner developed image area. There was no difference in the background quality for the overcoated versus the unovercoated photoreceptor. Continuous toner developed imaging of the overcoated photoreceptor was done and 4500 prints were obtained. The unovercoated photoreceptor failed after 2000 prints.

While the present invention has been described in detail with particular reference to preferred embodiments thereof, it will be understood that variations and modifications can be effected within the scope of the invention as described herein above and as defined in the appended claims.

#### Claims

1. An electrophotographic imaging member, including a substantially transparent layer comprising charge transport molecules and charge injection enabling species, characterised in that the charge injection enabling species is a copper (I) compound.
2. The electrophotographic imaging member of claim 1, comprising at least one photoconductive layer and an overcoating layer comprising said transparent layer.
3. The electrophotographic imaging member according to claim 1 or claim 2, wherein said copper (I) compound is cuprous halide.
4. The electrophotographic imaging member according to claim 3, wherein said copper (I) compound is cuprous iodide.

5. The electrophotographic imaging member according to any one of claims 1 to 4, wherein said charge injection enabling species is present in the form of a molecular dispersion.
- 5 6. The electrophotographic imaging member of any one of claim 1 to 4, wherein said charge injection enabling species are molecularly complexed with said charge transport molecules.
7. The electrophotographic imaging member according to any one of claims 1 to 4, wherein said charge injection enabling species comprises particles.
- 10 8. The electrophotographic imaging member of any one of claims 1 to 6, wherein said charge injection enabling species is dispersed in a film forming continuous phase.
9. The electrophotographic imaging member of any one of claims 1 to 8, wherein said transparent layer is insulating.
- 15 10. The electrophotographic imaging member of any one of claims 1 to 9, wherein said transparent layer comprises about 1 to about 25 weight percent of said charge injection enabling species based on weight of said transparent layer.

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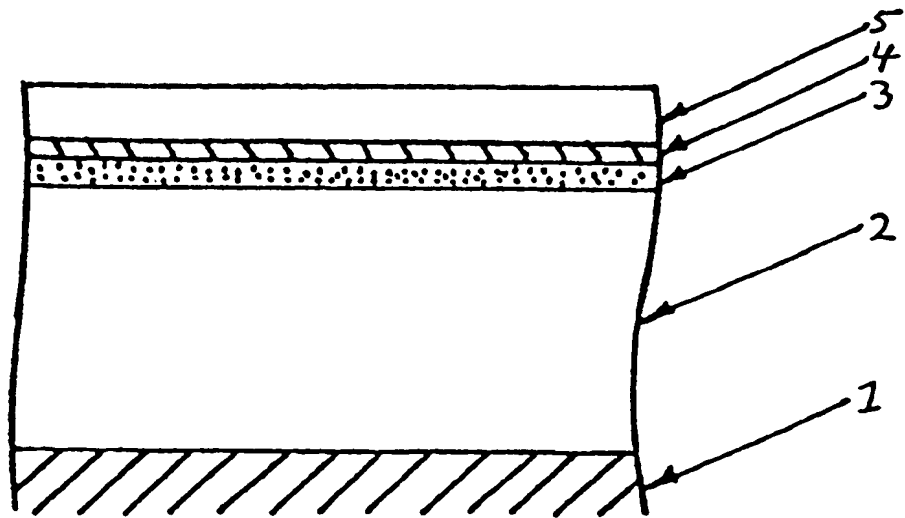
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**Transparent photoreceptor overcoatings.**

Highly transparent charge injection enabling species for electrophotographic overcoatings include copper (I) compounds dispersed throughout the overcoating or complexed into a charge transport matrix. The overcoatings contain an insulating, film forming continuous phase having charge transport molecules and the copper (I) compounds such as cuprous iodide.

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# EUROPEAN SEARCH REPORT

Application Number

EP 90 31 3542

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D, Y	EP-A-149914 (XEROX CORPORATION) * abstract * * page 16, line 8 - page 17, line 7 * * page 18, lines 11 - 12 * * claims 1, 4, 5 * ---	1-10	G03G5/147 G03G5/047 G03G5/087
D, Y	PATENT ABSTRACTS OF JAPAN vol. 8, no. 82 (P-268)(1519) 14 April 1984, & JP-A-59 159 (MINOLTA CAMERA K.K.) 05 January 1984, * the whole document * -----	1-10	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G03G
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05 JULY 1991	Examiner VOGT C.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons A : member of the same patent family, corresponding document	

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